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TWO INNOVATIVE, SIMPLE AND COST-EFFECTIVE SOLAR RETROFITS FOR THE MISSOULA SENIOR CITIZENS CENTER

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MONTANA DEPARTMENT of NATURAL RESOURCES and CONSERVATION

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TWO INNOVATIVE, SIMPLE AND COST-EFFECTIVE SOLAR RETROFITS FOR THE MISSOULA SENIOR CITIZENS CENTER

Prepared by

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430 South Fifth West
Missoula, Montana 59801

Energy Options, Inc.
240 N. Higgins Avenue
Missoula, MT 59802

September 1984

Prepared for

Montana Department of Natural Resources and Conservation
1520 East 6th Avenue, Helena, Montana 59620
Renewable Energy and Conservation Program
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INTRODUCTION

In March of 1980, The Missoula Senior Citizens Association requested funds from the Dept of Energy Small Grants Program to hire Energy Options, Inc. to write a conservation/solar retrofit feasibility study concerning possible energy savings at their center. That study was funded and five recommendations were made by Energy Options, Inc.

1. Insulate the presently uninsulated 8000 sq. ft. attic space to an R-38;
2. Add clear mylar roll-down shades with side-track seals to act as summer/winter storms;
3. Install an outdoor lock-out aquastat that would shut down the inefficient steam boiler when the outside ambient temperatures exceeded 55 to 65 degrees;
4. Retrofit 1500 sq. ft. of the building's south wall to incorporate an unvented Trombe wall; and
5. Install hydronic flat plate collectors to help with the 400 to 600 gallons of hot water needed every day for an in-house food service program.

Subsequent to the feasibility study, the Association requested funding from the Dept. of Energy to undertake the proposed conservation and renewable projects. Primarily due to the large number of requests and the limited funds available, the Dept. of Energy was unable to fund this proposal.

The Association, with the assistance of Energy Options, Inc., then requested funding from the Montana Dept. of Natural Resources and Conservation for the solar domestic hot water system and the un-vented Trombe Wall (both with some modifications from the DOE proposal). The Association was notified in the Spring of 1982 that funding had been approved and the Grant Agreement was signed in April 1982.

In the Fall of 1982, the final designs for the solar domestic water heating system were prepared and the system was furnished and installed by Sun Craft of Bozeman, Mt at an installed price of $18,840.37 (Exhibit A). Initial problems with the collector sensors (see Discussion section) created some difficulties but by January of 1983 the system was on-line and performing better than had been expected. As warmer weather arrived, the system was reaching its high-temperature limit and shutting down earlier and earlier in the day. In order to take advantage of the excess capacity of the system, Energy Options, Inc. recommended to the Association that fan-convector units be installed in the basement and one office area upstairs to assist in heating those areas. All involved in the project agreed and four (4) Myson fan-coil convectors were installed in March and April of 1983 by Energy Options, Inc. at a total installed cost of $2,715.00 (Exhibit B).

Due to problems of timing, weather, financing, and shipping, the Trombe wall retrofit was not finished until August 1984.

Construction was sub-contracted to Energy Options, Inc. of Missoula for a total installed cost of $13,650 (Exhibit C). The construction of the wall was straight forward and no difficulties were encountered. Modification of the sun-screen suspension system to a roller mechanism (thus allowing one-person installation and removal) was performed by Energy Options, Inc. at an additional cost of $294.63 (Exhibit D). Although this did not cover the actual costs of the roller mechanism, this was the amount remaining in the grant funds and Energy Options, Inc. agreed to absorb the extra expense.

PROJECT DESCRIPTION

Solar Domestic Water Heating System

The solar domestic water heating system (Fig. 1) consists of twelve (12) Sunmaster TRS-81 Evacuated Tube Solar Collectors for a total of 282 sq. ft. of aperture. These collectors are mounted at 60 degrees on the flat roof of the Center and are facing due south. Collector supply plumbing is 3/4" Type M copper and return plumbing is 1 1/4" Type M copper. Both supply and return plumbing are insulated with R-7 jacketed pipe insulation. Hot water storage is contained within two (2) 120 gallon Solar Plus tanks (Bock Corporation Model 120SSW) with internal heat exchangers and one (1) 120 gallon unpressurized Solar Plus drain-back and surge tank (Bock Corp. Model 120S). The system is controlled by a Sunmaster Differential Control (modified IE C-30 Control) with collector over-temperature protection and storage high limit protection. The solar collection fluid consists of water and is circulated through the system by two (2) Grundfos stainless steel pumps (Model UP25-64F) running in series.

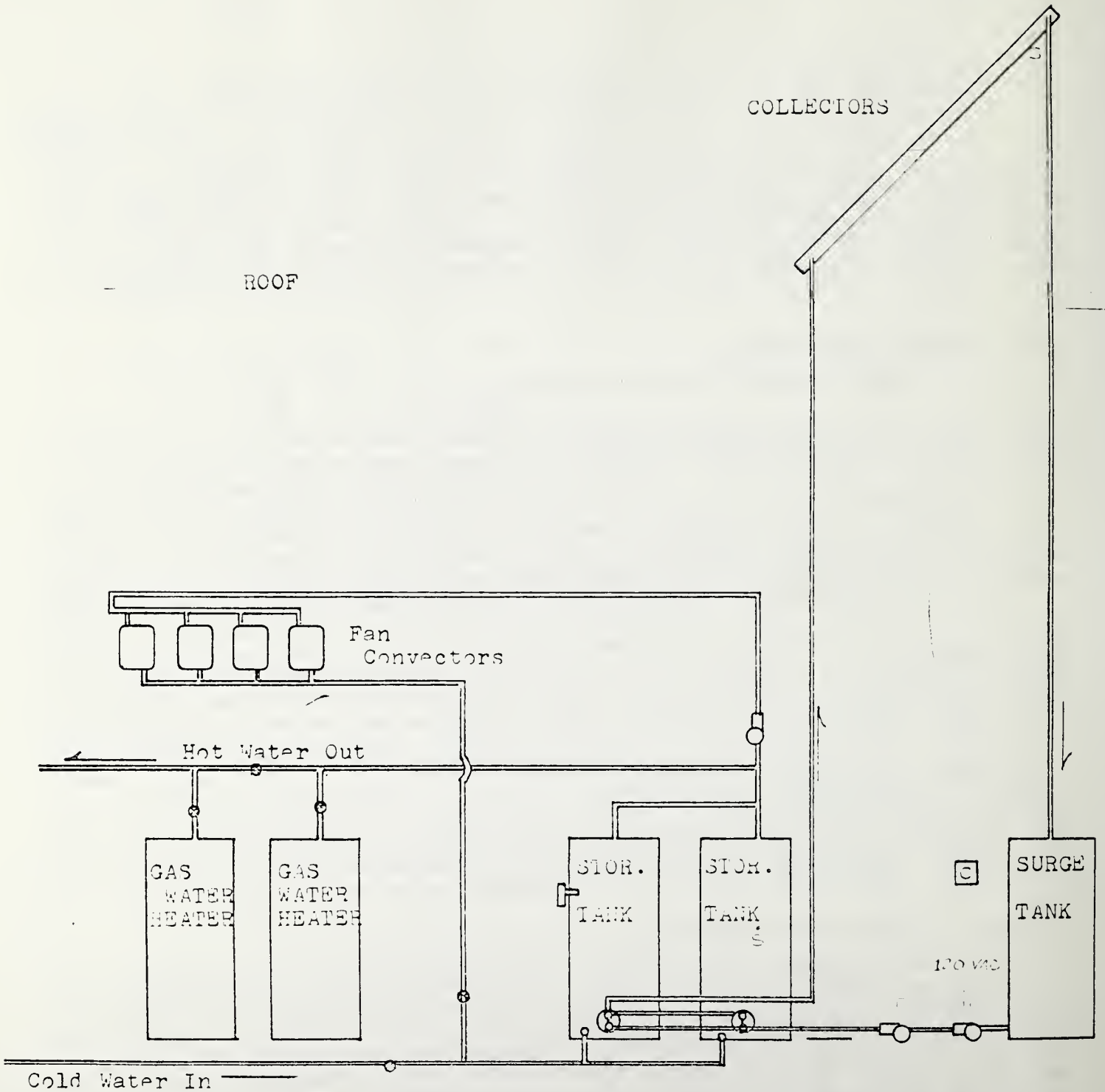
Excess heat from the solar system is distributed to the basement and one office on the main floor through four (4) Myson Model 14 fan-coil convectors rated at 10,000 to 14,000 BTU's per hour (depending on water inlet temperatures).

Operation of System

When temperatures within the collector array are sensed to be higher than in the storage area by the Sunmaster Differential Control, the control activates both Grundfos pumps. Water is pumped from the surge tank, through the internal heat exchangers within the storage tanks, and up to the collectors. When the collectors are filled, the water overflows into the return line and falls back into the surge tank. From here it again is pumped through the internal heat exchangers, giving up its collected heat to the storage tanks and thence to the collectors to be heated again. The control system continually monitors the storage tank temperature and, if this temperature exceeds a preset limit, the control will shut the pumps off. The control system also monitors the collector temperature and will prevent the pumps from being activated should the collectors exceed a preset temperature. This

Fig. 1

SOLAR DHW SYSTEM



⊗--- shut-off valve
pump
internal heat exchanger
S sensor
C control
direction of flow

action is to prevent the collectors from filling with cold water during a period when thermal shock could damage the evacuated tubes.

Delivery of heat to the basement and office area is controlled by an "and" type of logic. That is, if any of the four fan convectors are calling for heat and the storage water temperature is above a pre-selected temperature, a stainless steel Grundfos pump is turned on which pumps hot water to the convectors. When the pumped water in the convectors exceeds 110 degrees, an internal fan is activated which moves heated air into the conditioned space.

Discussion

The system has been operating now for about 1 year. Three problems have occurred with the system, all of which have been solved although the solution to the second problem is not entirely satisfactory. The first problem was a series of failures in the collector sensor which caused the system to shut down. This sensor was replaced several times but the cause of the failure was never determined. After grounding the collector system, this problem never recurred. Whether or not induced electrical currents (from overhead power-lines?) in the collector array were the cause is not known.

The second problem was related to the control logic of the system and the systems basic design. When the controller senses the collectors to be cooler than the storage tank it shuts the pumps off. However, due to the design of the system, draining of the evacuated tubes was slow enough such that, during sunlight hours, the fluid in the tubes would boil before the tubes were completely drained. This was primarily a problem in the summer when both ambient temperatures and solar radiation were high. Because the storage high limit sensor could not be set to a lower temperature, a timer was installed on the system which limits the time during which the system runs each day. By limiting run-time of the system, storage tank temperatures are held below that temperature above which boiling of the collector fluid would occur during drain-back of the system. Although this solution has solved the problem, it has also reduced the total amount of heat being collected by the solar system. It appears the ideal solution would be to modify the design of the collectors to allow much more rapid draining of the tubes. It is anticipated this will be attempted prior to next summer (1985).

The third problem with the system was not caused by any system components or installation but rather by a change in use of the building. When the system was originally conceived and designed there was a low-income food preparation service in the building. This service required a large amount of hot water for food preparation, dish-washing, and clean-up. This service was subsequently moved out to another location and hot water requirements fell considerably. As a result, the solar system was producing far more hot water than was needed and was, therefore,

not being used anywhere near its capacity. In order to make use of this additional capacity, four fan convector units were installed in the building to provide additional space heating. These were wired to an aquastat in the storage tanks such that the convectors could be activated by a call for heat anytime the storage tanks were above a pre-set temperature. At the present time, this pre-set temperature is 120 degrees. Although the fan convectors can extract heat from water temperatures lower than this, this temperature was chosen because it is still hot enough for domestic purposes. At the present time, this solution appears to be working well.

Monitoring equipment was installed on the system by Energy Options soon after its installation. Due to faulty equipment, no useful information was obtained during the first months of the system's operation. In the Summer of '85, the Montana Dept. of Natural Resources and Conservation awarded a grant to SunCraft of Bozeman to monitor the system. That monitoring program occurred during the Summer of '84 and the results have not yet been released.

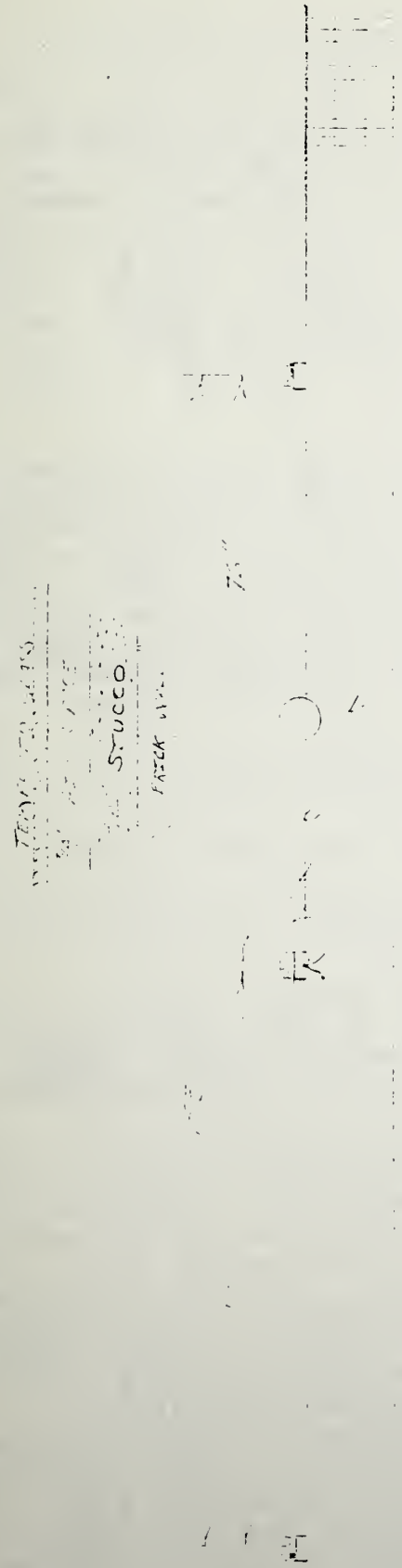
Trombe Wall

The Trombe wall (Fig. 2 & Exhibit E) is constructed directly on the south-facing solid brick wall of the Center and consists of three (3) separate panel areas , each of which is composed of 4 foot wide by 6.5 foot high modules. Overall panel height is 13 feet and total width is 66 feet 7 inches for a total area of 866 square feet.

The modules were initially framed in with 2" by 4" cedar lumber to allow later installation of 46" wide by 76" high glazing panels. The cedar framing was fastened to the brick wall with 3" lag bolts and shields (3' on center) combined with a temperature-resistant construction glue. After the initial framing, the brick wall inside the framing was covered with metal lath and plaster to a thickness of 3/4". The plaster was then covered with a selective surface foil with self-adhesive backing (trade name Sunsponge). Finally, low-iron, white-water, non-glare tempered glass was mounted on the exterior surface of the cedar framing. Idea Development bronze anodized aluminum with EPDM gaskets was used for the glazing mounting battens.

When the use of a selective surface foil was first proposed there was concern the foil would be difficult to install and would not adequately adhere to the stucco surface. Actual experience showed that the foil was relatively easy to install. The only problem experienced was that, even though the foil was absolutely flat during and immediately after installation, there was a tendency for it to 'bubble' or 'wave' within a few minutes after installation. When it was again rolled it would flatten out but, because the foil had obviously expanded, this second rolling would create small wrinkles in the surface. This does not appear to decrease the effectiveness of the foil and is hardly noticeable behind the glazing. Adhesion of the foil was also not a problem.

FIG. 2 . TROMBE WALL SECTION



In fact, if the foil inadvertently touched the stucco finish it could not be removed. The only solution was to cut it loose! Whether this excellent adhesion will continue over time is unknown, but after 3 months there is no evidence of de-lamination.

In order to prevent possible over-heating of the wall and the building during the summer months, a solar screen (VIMCO Eclipse Solar Screening) was mounted on a roller system (designed by Energy Options, Inc.) at the top of the panels (Fig. 3). This roller system allows the screen to be raised and lowered by one person. A specially-fabricated flashing was then placed over the roller system to protect the screening from the weather.

Discussion of System

Because this is a passive solar wall, there is no mechanical system involved. The selective surface simply absorbs heat from the sun's rays (even on cloudy days!) and the brick wall conducts this heat into the building. Preliminary monitoring indicates this transfer of heat requires about 8 hours. That is, from the time the sun begins heating the 12" thick wall until the interior wall surface begins rising in temperature about 8 hours has elapsed.

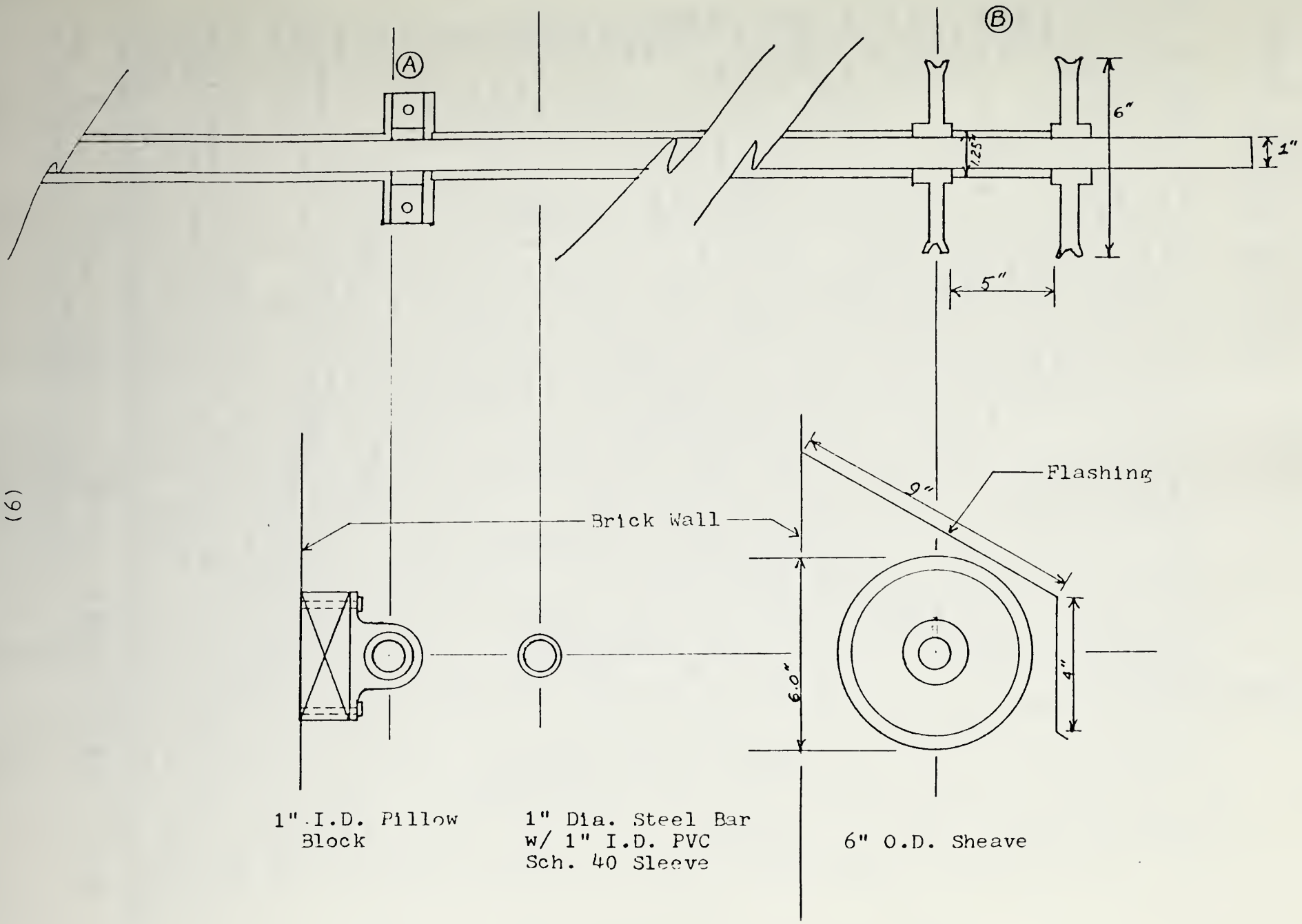
Monitoring of the system was begun in late September, 1984. Temperature sensors have been placed in the following areas:

1. collector air space between glazing and wall;
2. 1", 3", 5", 9", and 11" from outside surface of wall behind the collector;
3. 1" deep in outside surface of south wall where there is no collector; and
4. 1/2" deep in interior surface of south wall where there is no collector on the exterior wall.

Recording of temperatures was through manual reading of an electronic 12-channel thermometer. This method is not entirely satisfactory due to inability to obtain readings between about 6 P.M. and 8 A.M. However, several observations can be made from the data which has been collected.

A maximum temperature of 160 degrees in the airspace and 175 degrees 1" beneath the selective surface was recorded on Oct. 10, 1984. This day was clear with a maximum ambient air temperature of 74 degrees. Because the sun angle at this time of the year is fairly low (approximately 35 degrees) and because the air temperature was comparable to a summer day, it is believed these temperatures may be the maximums obtained within the collector even during the hotter summer months. If this is the case, there appears to be no cause for concern that the cedar framing within the collector will deteriorate due to excessive temperatures.

The next highest temperatures recorded in the collector occurred on Nov. 5, 1984; 147 degrees in the air space and 159 degrees 1" beneath the selective surface. This day was also very sunny but the average daytime temperature was 40 degrees. Temperature readings for this day were taken at 8:40 AM, 2:15 PM,



SOLAR SCREEN ROLLER MECHANISM

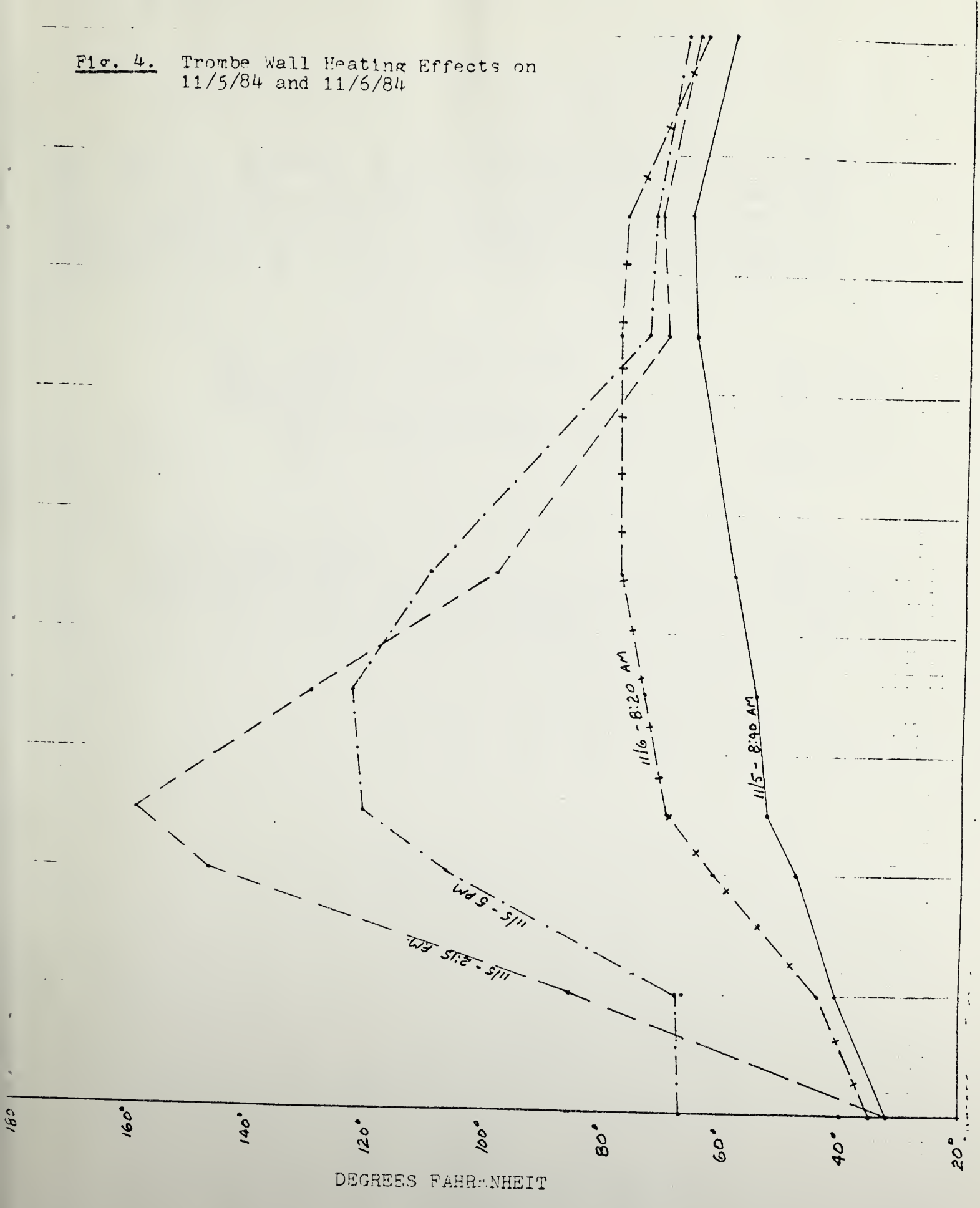
Fig. 3. Sun Screen Roller Mechanism

and 5:00 PM. In order to see the effects of the wall-heating on this day, another reading was taken at 8:20 AM the following day. These four readings have been plotted on a graph (Fig. 4). The 'x' co-ordinate begins with Outside Air, then Exterior Wall (no collector), then Collector Air, then successive depths through the brick wall, and finally Interior Wall (no collector). The 'y' co-ordinate is the temperature in degrees Fahrenheit. The lowest curve (solid line) is the beginning temperatures on Nov. 5. These readings were taken after several successive days of cool, cloudy weather. At this time, the interior of the building was losing heat through the Trombe wall. Since the temperature (60 degrees) of the wall where there is no collector was lower than the wall temperature (65 degrees) behind the collector, it can be deduced that the collector wall area was losing heat less rapidly than the non-collector wall area. This is to be expected, since addition of the stucco, selective surface foil, and glazing would raise the R-value of the wall and, thus, reduce the heat loss through it. The next reading was taken at 2:15 PM. At this time, the Trombe wall surface had reached a temperature of 159 degrees and the 5" depth area had increased to 99 degrees. At the 9" depth, the temperature had increased to 71 degrees from 66 degrees. It is not known whether this increase was due to conduction of heat from the exterior Trombe wall or from an increase in temperature in the interior of the building (due to day thermostat set-up). By 5:00 PM, the sun had set and the exterior wall temperatures were falling but the interior wall temperatures at 5", 9", and 11" were still climbing. By this time, the temperature at the 9" depth had risen to 74 degrees (2 degrees warmer than the interior air temperature) and was, thus, definitely being effected by the wave of heat passing through the brick wall. The last temperature measurement was taken the next morning at 8:20 AM. Overnight temperatures had dropped below freezing and this was reflected in the exterior wall non-collector area temperature of 42 degrees. Collector air temperature was 61 degrees, and at depths of 3, 5, 9, and 11 inches the temperatures were 74, 78, 79, and 78 degrees, respectively. These elevated temperatures indicate that at no time during the night did this wall area lose heat and, in fact, that heat was being delivered to the building from about 5:00 PM until at least 8:20 the next morning. Due to the lack of continuous temperature recording, it is not known whether these morning temperature readings represent maximum temperatures reached and, if not, whether the maximum was reached prior to or after the measurement was taken at 8:20 AM.

On Oct. 25 the weather was cool and cloudy and had been that way the previous two days. Collector air and surface temperatures at 8:15 AM were 59 and 65 degrees. By 12:15 PM these temperatures had risen to 65 and 70 degrees indicating that the wall will collect heat even on cloudy days. Although this heat may never find its way into the building, it does decrease the heat loss out of the building.

Energy Options, Inc. plans to continue monitoring of the Trombe Wall through-out the winter of '84-'85. It is hoped that a

Fig. 4. Trombe Wall Heating Effects on 11/5/84 and 11/6/84



continuous recording thermometer can be installed in order to better determine heat-flow through the wall. Due to the replacement of the old boiler with high-efficiency boilers during the summer of '84 it will not be possible to determine energy savings from energy use reductions. At this time, it is known that the Trombe Wall is working as designed and is delivering heat to the conditioned space.

FINANCIAL REPORT

TOTAL COST OF PROJECT

SOLAR DOMESTIC HOT WATER SYSTEM	$18,840.00
FAN CONVECTORS	2,715.00
TROMBE WALL	13,650.00
SUN-SCREEN ROLLER MECHANISM	295.00
TOTAL	$35,500.00

TOTAL FUNDED AMOUNT	$35,500.00
TOTAL AMOUNT PAID	30,000.00
TOTAL REMAINING FUNDS TO BE DISBURSED	5,500.00

PROPOSAL

EXHIBIT A

SUN CRAFT
BOX 1146 PH: 587-3442
BOZEMAN, MT 59715

Copy

Proposal No. DHW-C-(

Sheet No. 1

Date 10/27/82

Proposal Submitted To	Work To Be Performed At
Name Palmer E. Johnson	Street 705 South Higgins Avenue
Street Missoula Senior Citizens Assoc.	City Missoula Senior Citizens Center
City 430 South Fifth Street West	State Missoula
State Missoula	~~Date of Plans~~
Telephone Number Montana 59801	~~Architect~~
(406) 543-7154	

We hereby propose to furnish the materials and perform the labor necessary for the completion of

A solar domestic hot water system for The Missoula Senior Citizens Center. Collector array will consist of twelve (12) Sunmaster TRS-8 Evacuated Tube Solar Collectors (282 sq. ft. net aperture) and will be flat roof mounted at 60 degrees. Collector supply plumbing will be 3/4" Type M copper and return plumbing will be 1-1/4" Type M copper and both will be insulated fully with R-7 polyisocyanurate jacketed pipe insulation. Collector working fluid will be distilled water and will be contained by a 125 gallon unpressurized fiberglass R-14 insulated drain-back tank (SunSet Solar). Working fluid (collec pumps will be series-connected Grundfos UP 25-64 stainless steel (2 total). Collector-storage differential control will be Sunmaster Differential Control (modified IE C-30 Control) with collector over-temperature protection and storage high limit protection. Collector loop/DHW loop heat exchangers will be 2 finned copper coils mounted internally in the solar storage tanks. Solar storage tanks will be two (2) parallel connected 120 gallon insulated tanks. Total solar

All material is guaranteed to be as specified, and the above work to be performed in accordance with the drawings and specifications submitted for above work and completed in a substantial workmanlike manner for the sum of

with payments to be made as follows:

Dollars ($18,840.37).

$6000 advance upon acceptance of proposal and submittal of statement from SunCraft. Remaining payments according to Grant Agreement #RAE-82-1010 upon completion of Milestones 1 & 2.

Any alteration or deviation from above specifications involving extra costs, will be executed only upon written orders, and will become an extra charge over and above the estimate. All agreements contingent upon strikes, accidents or delays beyond our control. Owner to carry fire, tornado and other necessary insurance upon above work. Workmen's Compensation and Public Liability Insurance on above work to be taken out by

SunCraft, as necessary

Respectfully submitted

SunCraft Appropriate Energy Alternatives, Inc.

Per Dale Tutzauer / Robert Knebel

Note — This proposal may be withdrawn by us if not accepted within 30 days

ACCEPTANCE OF PROPOSAL

The above prices, specifications and conditions are satisfactory and are hereby accepted. You are authorized to do the work as specified. Payment will be made as outlined above.

Date

Signature

Signature

storage capacity (including drain-back tank) will be 360 gallons (1.3 gallons per sq. ft. collector) which is within range recommended by Sunmaster Corporation. Solar storage tanks will be series connected to two (2) existing natural gas water heaters and plumbed to permit by-passing and shutdown of either the solar DHW system or the existing water heaters. Solar storage tank plumbing will be insulated with R-4 Neoprene pipe insulation and the existing water heaters will be fitted with insulation jackets and bimetallic flue dampers. A tempering valve will be provided to control DHW delivery temperature. All solar collector and DHW loop plumbing will be joined with 95-5 tin-silver solder. Solar storage tanks will be provided with dielectric unions, isolation valves boiler drain valves and pressure-temperature relief valves. Pumps will be provided with fused switch boxes and armored cable conduit. Instrumentation for the system will include four (4) General Instruments Thermometers with Thermowells and one (1) Blue/White High Temperature Polysulfone Flowmeter for the collector loop.

All equipment to be used in the job will be shipped to Energy Options, 236 North Higgins Avenue, Missoula, MT 59801.

All work will be completed within 90 days of receipt of the $6000 advance for downpayment on materials.

Bonding for the job will be taken out through First West Insurance and Bonding Company of Bozeman, Montana.

SunCraft will abide by the stipulations and conditions set forth in Grant Agreement # RAE-82-1010 and the letter dated 10/12/82 to SunCraft from Palmer E. Johnson of the Missoula Senior Citizens Association.

All normal warranties given by Sunmaster Corporation and by other equipment manufacturers will be extended to the Missoula Senior Citizens Association through SunCraft. Additionally SunCraft will provide a one-year warranty on workmanship and installation of the proposed solar DHW system. SunCraft will also provide an operating manual for the system which includes manufacturer's product literature and warranties, operation and maintenance instructions, and any other drawings, materials lists, and instructions which are applicable.

SunCraft Dale Pickard Robert Knebel

ACCEPTANCE OF PROPOSAL

Missoula Senior Citizens Association

DATE _____ SIGNATURE _____

SIGNATURE _____

EXHIBIT B

1065

ENERGY OPTIONS, INC.
236 N. Higgins
MISSOULA, MT 59802

(406) 721-2733

TO Missoula Senior Citizens Center
705 South Higgins
Missoula, Mt. 59801

DATE 3/29/83 JOB NO.

JOB NAME RAE 821010

JOB LOCATION SAME

TERMS

DESCRIPTION	PRICE	AMOUNT

To: Missoula Senior Citizens Center
Re: Adding fan coil units to existing solar system

Energy Options, Inc. hereby agrees to provide and install four (4) liquid fan convectors to the existing solar domestic hot water system for a total sum of One Thousand Seven Hundred Fifteen Dollars ($1,715.00).

Four fan convectors shall be placed in the basement at appropriate locations and duct work to heat to the rooms when the solar hot water tanks is used to degrees in temperature. This is to insure that domestic hot water is available to the Center at all times. By adding fan coil units the Center is able to use excess heat generated by the solar tube solar collectors for the building heat load during three or four days of clear sunny weather. Otherwise much of the heat would be wasted and the existing controls currently shut down the solar system due to overheating.

One thermostat will be installed and will control all four convectors and turn them on when [illegible] call for heat and the solar tank is at the present temperature. The existing stainless steel circulating pump will circulate the water to the convectors, and [illegible] operated when call for the pressure side of the [illegible] return the cooler water to the storage tank.

We estimate that [illegible],000 BTU's of free heat could be generated per [illegible] during periods of sunny weather, and that [illegible] system will extract 10,000 [illegible],000 BTU's depending on the temperature [illegible].

The total cost of [illegible] delivered to Missoula is $1,617, and the remaining $98 [illegible] labor cost provided by Energy Options at $5 per hour ($7.00 per hour two people two days). ...IT IS VERY IMPORTANT TO [illegible] BASED ON THIS PART OF THE PROJECT SINCE WE ARE USING [illegible] USABLE HEAT DUE TO LOWER HOT WATER [illegible] THE SUMMER MONTHS.

Scott Spaulding 3/29/83

ORIGINAL

Thank You

ENERGY OPTIONS INC.
Energy Saving Alternatives
240 N. Higgins
MISSOULA, MONTANA 59802

(406) 721-2733

1020

TO Missoula Senior Citizens Center
705 S. Higgins Ave.
Missoula, MT 59801

DATE Sept. 1, 1984 JOB NO.

JOB NAME RAE 82-1010

JOB LOCATION

TERMS

DESCRIPTION	PRICE	AMOUNT
TO: Missoula Senior Citizens Center RE: Roller mechanism to sun screen system		
Total amount due Energy Options, Inc. for addition of roller mechanism to sun-screen system and installation of flashing to protect same from weather.		$295.00

ORIGINAL

Thank You

EXHIBIT D

ENERGY OPTIONS INC.
Energy Saving Alternatives
240 N. Higgins
MISSOULA, MONTANA 59802

(406) 721-2733

1020

TO Missoula Senior Citizens Center
705 S. Higgins Ave.
Missoula, MT 59801

DATE Sept. 1, 1984 JOB NO.

JOB NAME RAE 82-1010

JOB LOCATION

TERMS

DESCRIPTION	PRICE	AMOUNT
TO: Missoula Senior Citizens Center RE: Roller mechanism to sun screen system		
Total amount due Energy Options, Inc. for addition of roller mechanism to sun-screen system and installation of flashing to protect same from weather.		$295.00

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Thank You

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